# Overview of the Intercomparison of 3D Radiative Codes (I3RC) project

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## I3RC GOALS

- Compare 3D atmospheric radiative transfer models
- Provide benchmark results for model testing
- Create a community 3D Monte Carlo radiation code
- Publish web-based resources on 3D radiative transfer

I3RC phases 1 & 2 timeframe: 1999 to 2005.
Phase 3 started with a workshop in November 2005.

## SUMMARY

- **Phase 3 has provided on-online tools widely used by the 3D radiative transfer community, including a community model for 3D radiative transfer simulations.**

- **Phase 3 intercomparisons provided reference results for testing future 3D radiative transfer models, and revealed strengths and weaknesses of a variety of simulation techniques.**
- **All are invited to take advantage of I3RC reference results, community code, and other resources.**

## I3RC WEBSITE

**http://i3rc.gsfc.nasa.gov/**

Website features:
- Intercomparison results from Phases 1 & 2
- Abstracts of over 300 papers on atmospheric 3D radiative transfer
- Links to free publicly available codes:
  - 3D radiative transfer codes
  - Models creating heterogeneous cloud structures
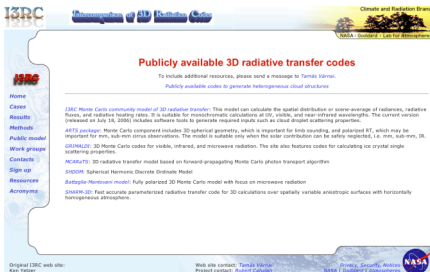


## I3RC COMMUNITY MODEL OF 3D RADIATIVE TRANSFER

- Development led and coordinated by Robert Pincus.
- Released in July 2006 through I3RC website.
- Validated for I3RC phase 1 & 2 cases.
- In 2007, user downloads occurred more than once a week
- Calculates radiative fluxes, heating rates, and radiances
- Provides both scene average values and complete fields
- Performs simulations for single wavelength, Lambertian surface

## I3RC INTERCOMPARISONS
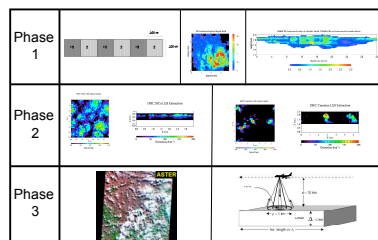


## MODELS PARTICIPATING IN PHASE 3 INTERCOMPARISONS

- DZLR1: Monte Carlo
- DZLR2: Monte Carlo with phase function truncation
- DZLR3: Monte Carlo with δ-scaling
- IAOT1 (Inst. Of Atmos. Optics, Russia): Monte Carlo
- ICMMG (Inst. Comp. Mat. & Math. Geophys., Russia): Monte Carlo
- JAMS1 (Jap. Agency Mar. Earth Syst. Tech., Japan): Monte Carlo
- MIUB1 (Univ. of Bonn, Germany): forward Monte Carlo
- MIUB2 (Univ. of Bonn, Germany): backward Monte Carlo
- URDG6 (Univ. of Reading, UK): time-dependent two-stream (TDTS)
- URDG5 (Univ. of Reading, UK): TDTS + PVC (photon var.-covar.)
- UMBC6 (Univ. of Maryland, Balt. County, USA): Monte Carlo

## CASE 6: Cumulus clouds in Brazil

Simulate 0.67 μm satellite reflectances at 1 km resolution
for nadir and for 60° forward and back scattering directions.
$\theta_0 = 41°$, $\phi_0 = 23°$. Rayleigh and aerosol scattering included.
Surface: Li-Sparse-Ross-Thick model.
Scene parameters from MODIS TERRA products.
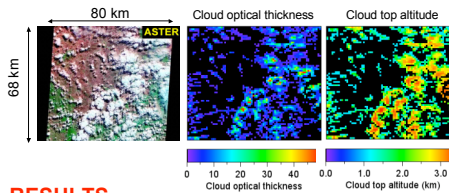


### RESULTS

**Forward vs. backward Monte Carlo (MIUB1 vs. MIUB2):**
- Backward & forward simulations agree well.
- Estimated simulation uncertainties consistent with pixel-differences between the two models. (0.007 vs. 0.009 on average).
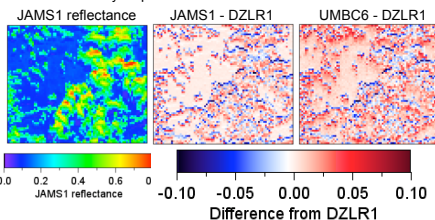- MIUB surface reflectances too low.

**Phase function truncation, δ-scaling (DZLR1, 2, 3):**
- Phase function truncation does not cause any systematic errors.
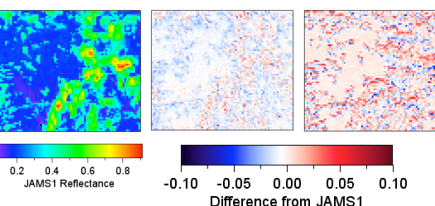- δ-scaling reduces cloud reflectance values by 2-3% (0.005-0.01).
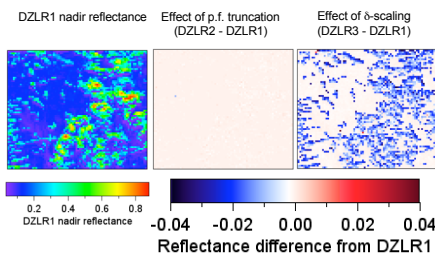


**Cloud reflectances:**
- For forward view, DZLR1 yields brighter sunlit slopes and darker shadowy slopes than JAMS1 or UMBC6.
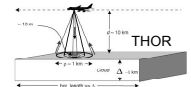


**Surface reflectances:**
- UMBC6 gives darker surfaces near clouds than JAMS1 or DZLR1.



## CASE 7: 3D spread of lidar pulses

Simulate lidar return signals for thick clouds, as a function of time-delay and radial distance from spot.

Sample applications:
- Multiple scattering
- Multiview lidars



Case 7 experiments:

1. Semi-infinite cloud, isotropic scattering
2. Henyey-Greenstein phase function
3. Single scattering albedo = 0.98
4. Finite cloud: $\Delta z = 500$ m, $\tau = 20$
5. Mie phase function
6. Linear vertical profile

### RESULTS

**Monte Carlo models:**
- Very good agreement for isotropic and Henyey-Greenstein phase functions (Exp. 1-4).
- Increased differences for Mie phase function consistent with 5-10 times larger simulation noise (Exp. 5 & 6).
- JAMS1 slightly deviates for Henyey-Greenstein phase function, but not for isotropic & Mie cases.
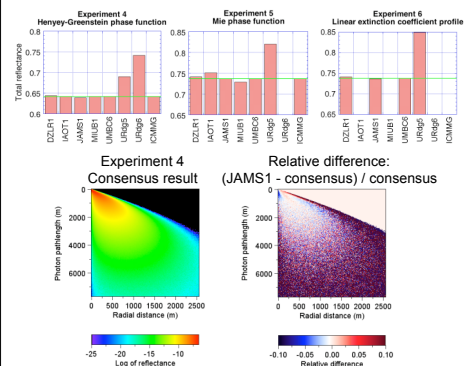




**Time-dependent two-stream method (TDTS + PVC algorithms):**
- Orders of magnitude faster than Monte Carlo method.
- Best suited for isotropic and Mie phase functions.
- PVC algorithm helps TDTS method even for Henyey-Greenstein phase function, but early returns at small radial distances still overestimated.
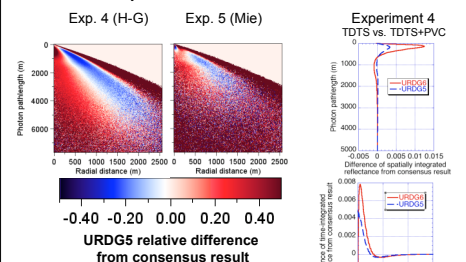
### REFERENCES:

Oreopoulos, L., A. Marshak, R. F. Cahalan, T. Várnai, A. B. Davis, and A. Macke, 2006: New Directions in the Radiative Transfer of Cloudy Atmospheres. *EOS,* **87**, No. 5, 31 January 2006.

Cahalan, R. F., L. Oreopoulos, A. Marshak, K. F. Evans, A. Davis, R. Pincus, K. Yetzer, B. Mayer, R. Davies, T. Ackerman, H. Barker, E. Clothiaux, R. Ellingson, M. Garay, E. Kassianov, S. Kinne, A. Macke, W. O'Hirok, P. Partain, S. Prigarin, A. Rublev, G. Stephens, F. Szczap, E. Takara, T. Várnai, G. Wen, and T. Zhuravleva, 2005: The International Intercomparison of 3D Radiation Codes (I3RC): Bringing together the most advanced radiative transfer tools for cloudy atmospheres. *Bull. Amer. Meteor. Soc.,* **86** (9), 1275-1293.